

ORDINANCE NO. 79-11

AN ORDINANCE FOR THE PURPOSE OF ADOPTING STORM
DRAINAGE STANDARDS FOR THE CITY OF FORT SMITH

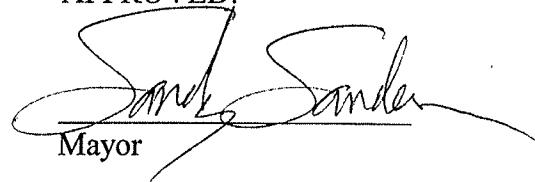
BE IT ORDAINED AND ENACTED BY THE BOARD OF DIRECTORS OF THE
CITY OF FORT SMITH, ARKANSAS, THAT:

SECTION 1: There is hereby adopted the 2011 Storm Drainage Standards, three (3) hard copies of which are now filed in the Office of the City Clerk and may also be viewed electronically at <http://www.fortsmithar.gov/engineering/default.aspx> ("Fort Smith Storm Drainage"), and which are hereby adopted and incorporated as fully as if set out verbatim herein, and the provisions thereof shall be controlling within the corporate limits of the City of Fort Smith, Arkansas.

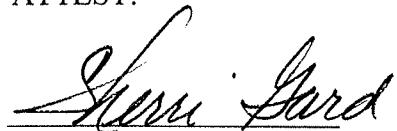
SECTION 2: Emergency Clause. It is hereby found and determined by the Board of Directors of the City of Fort Smith that an emergency exists in the City of Fort Smith, Arkansas, requiring adoption of the 2011 Storm Drainage Standards. This Ordinance being necessary for the immediate preservation of the public health, safety and welfare shall be immediately effective as of the date of its adoption.

PASSED AND APPROVED THIS 4th DAY OF October, 2011.

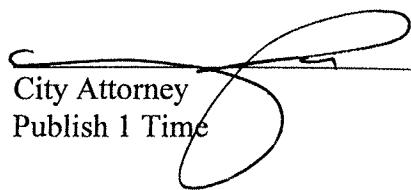
APPROVED:


Sandy Sander
Mayor

ATTEST:


Sherri Gard
City Clerk

Approved as to form:


City Attorney
Publish 1 Time

2011 Storm Drainage Standards



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STANDARDS AND REFERENCES

These drainage standards were developed from the following standards and references:

- AASHTO Model Drainage Manual, 1991 (Chapter 6)
- AASHTO Model Drainage Manual, 2005 (Chapters 2, 3, 5, & 6)
- AHTD Drainage Manual, 1982 (Chapter 4)
- City of Fayetteville, Arkansas, Drainage Criteria Manual (Chapters 1 & 5)
- City of Fort Smith, Arkansas, Minimum Storm Drainage Standards, 1975 (Chapters 1 – 4, & 6)
- City of Fort Smith, Arkansas, Drainage Policy, 1987 (Chapters 1, 3, & 6)
- FHWA, HDS No. 5, Hydraulic Design of Highway Culverts, 1985 (Chapter 4)
- NRCS, TR-55, Urban Hydrology for Small Watersheds, 1986 (Chapter 2)
- The Stormwater Manager's Resource Center, www.stormwatercenter.net (Chapter 5)

All other references are as noted within this document.

CHAPTER 1 – GENERAL REQUIREMENTS

1.1 GENERAL

No storm drainage facility – whether an enclosed structure, pipe, or an open channel, ditch or stream – shall be constructed, altered, or reconstructed within a subdivision, planned development, or a developed area, within a public right-of-way or easement, or discharge into, upon, or under a public right-of-way or easement, or a subdivision or planned development or developed area within the planning jurisdiction of the City of Fort Smith, without first obtaining written approval from the Department of Engineering.

1.2 DESIGN DATA, MAPS, COMPUTATIONS, PLANS, AND SPECIFICATIONS

All designs, plans and specifications submitted to the City for approval for the construction of public drainage works as required herein shall be prepared by a registered professional engineer, licensed in the state of Arkansas, and shall meet the minimum standards specified herein. All public improvements shall be constructed in accordance with the City of Fort Smith Standard Specifications for Public Works Construction and all applicable revisions and the City of Fort Smith Standard Drawings.

For private drainage works, all designs, plans and specifications submitted to the City for approval shall be prepared by a registered professional engineer, licensed in the state of Arkansas, and shall meet the minimum standards specified in Chapters 1 and 2. Drainage ways traversing private developments (i.e. ditches, culverts, storm drains) shall be public, and therefore, shall be subject to the minimum standards specified for public drainage works.

1.2.1 *Drainage Report*

A drainage report must be submitted for review and approval by the Engineering Department. The drainage report shall include the following:

1.2.1.1 Title and Date

The drainage report must include a title page which shows the title of the project and date of submission.

1.2.1.2 Location of Project

The street address and a vicinity map shall be included. The vicinity map must show the location of the project with respect to well-known roads, streets, subdivisions, survey lines, and/or City monuments.

1.2.1.3 Description of Project

A brief description of the project and the planned improvements must be included.

1.2.1.4 Contact Information

The name, address, and telephone number of the Project Owner and Developer must be included.

1.2.1.5 Drainage Area Map

A topographic area map with the pre- and post-development drainage area(s) outlined shall be provided. The map shall have a minimum of two foot contour intervals and a minimum scale of $1'' = 200'$.

1.2.1.6 Area Drainage Issues

A description of any known on- or off-site drainage/flooding problems shall be provided.

1.2.1.7 Written Summary of the Proposed Improvements

The summary must include on-site improvements, off-site improvements, condition of the downstream receiving areas, existing problems, any increases in flows, detention or lack of detention, and final conclusions.

1.2.1.8 Pre- and Post-Development Flowrates

All pre- and post-development flowrate calculations must be included for the 10-, 25-, 50-, and 100-year storm events.

1.2.1.9 Storm Water Detention Design

All calculations must be included.

1.2.1.10 Open Channel Flow Design

All calculations must be included.

1.2.1.11 Pavement Drainage Design

Calculations for gutter spread must be included.

1.2.1.12 Culvert Design

All calculations (both inlet and outlet control) must be included.

1.2.1.13 Inlet Design

Capture efficiency calculations must be included.

1.2.1.14 Storm Sewer Design

All storm sewer design and hydraulic grade line calculations must be included.

1.2.1.15 100-Year Water Surface Elevation and Minimum Floor Elevation

Calculations must be included for the water surface elevation resulting from the 100-year storm for all overland flow, including flow in the streets, parking lots, swales, and between lots. Minimum floor elevations must also be included. Minimum floor elevations shall be one foot above the calculated 100-year water surface elevation of open channels, swales, or overland flow.

1.2.1.16 Federal and State Requirements

Copies of documents which show compliance with all applicable Federal and State requirements (Corps 404 Permit, ADEQ Notice of Intent, FEMA CLOMR, etc.) must be included. Proof of permit approvals must be submitted before construction may begin.

1.2.1.17 Certification by Registered Professional Engineer

The title sheet of the drainage report shall be sealed, signed, and dated by a Professional Engineer registered in the state of Arkansas.

1.2.2 *Plan Requirements*

Plans shall be submitted on 22" x 34" sheets, unless another size is approved by the Engineering Department. All plans submitted for review shall include the following:

1.2.2.1 Location of Project

A vicinity map must be included. The vicinity map must show the location of the project with respect to well-known roads, streets, subdivisions, survey lines, and/or City monuments.

1.2.2.2 Plan and Profile Views of All Proposed Improvements

Plan and profile views must show the location, size, flowline elevations, gradients, materials, boring information and rock elevations (where applicable), and depths and sizes of adjacent or crossing utilities and structures.

1.2.2.3 North Arrow and Scale

A north arrow and scale must be shown on every applicable sheet. The top of each page shall either be north or east, unless otherwise approved by the Engineering Department. Plan drawings shall be prepared with a horizontal scale of 1" = 20' or larger. Profile drawings shall be prepared with the same horizontal scale as the plan drawings and a vertical scale of 1" = 5' or

larger. Cross sections shall have a horizontal scale of 1" = 10' or larger and a vertical scale of 1" = 5' or larger. Special cases may warrant the use of larger or smaller scale drawings and may be used with prior permission of the Engineering Department.

1.2.2.4 Bench Mark

At least two permanent bench marks must be established. Bench marks must be tied to the City of Fort Smith Coordinate System.

1.2.2.5 Right-of-Way

Plans must show the existing and proposed right-of-way or easements.

1.2.2.6 Existing Structures and Utilities

Plans must show the location of all existing structures, streets, driveways, storm drains, fences, trees, landscaping, utilities, and other features within 25 feet of proposed improvements. The flowline elevations of all existing drainage facilities must be shown. Where conflicts may occur between existing underground utilities and new construction, the elevations of the existing utilities must be determined by excavation methods.

1.2.2.7 Cross Sections

Cross sections must be provided at a maximum of 50 foot intervals along the centerline of proposed improvements for a minimum width of 50 feet, or as necessary to ensure drainage and define existing conditions of adjacent lands. Cross sections must show surface elevations, flowline elevations and sizes of all proposed improvements, and flowline elevations and sizes of all crossing or adjacent utilities or structures.

1.2.2.8 Stationing

Stationing shall be provided along the centerline of the proposed improvements. The stationing of street plans and profiles shall be from left to right and downstream to upstream in the case of channel improvement/construction projects, unless otherwise approved by the Engineering Department.

1.2.2.9 Details

Details must be provided on the plans for any structure requiring special design and not included in the City of Fort Smith Standard Drawings.

1.2.2.10 Floodplain and Floodway

FEMA regulated floodplain and floodway boundaries must be shown on the plans.

1.2.2.11 100-Year Water Surface Elevation and Minimum Floor Elevation

The water surface elevation resulting from the 100-year storm for all overland flow, including flow in the streets, parking lots, swales, and between lots, shall be shown on the plans. Minimum floor elevations for all lots must also be shown on the plans. Minimum floor elevations shall be one foot above the calculated 100-year water surface elevation of open channels, swales, or overland flow.

1.2.2.12 Erosion and Sediment Control Plan (Stormwater Pollution Prevention Plan); Grading Plan (Site Plan)

For construction sites that will disturb one or more acres, an Erosion and Sediment Control Plan (Stormwater Pollution Prevention Plan) identifying the type, location, and schedule for implementing erosion and sediment control measures, including appropriate provisions for maintenance and disposition of temporary measures, must be included in the plans. A Grading Plan (Site Plan) which shows the area to be disturbed and expected project sequencing, as well as the location and type of erosion controls to be installed, must be included with the Erosion and Sediment Control Plan. The Erosion and Sediment Control Plan and the Grading Plan must comply with the City of Fort Smith Fill and Grading Ordinance and with all applicable regulations set forth by the Arkansas Department of Environmental Quality.

1.3 RIGHT-OF-WAY AND EASEMENTS

All public drainage improvements shall be located in street right-of-way or in an easement dedicated to public use of the minimum widths as shown below:

1.3.1 *Enclosed Structures*

Enclosed structures require a minimum width of 15 feet or the width of the structure plus 10 feet, whichever is larger. Where required, an access easement shall also be provided.

1.3.2 *Open Channels*

Open channel easements shall be required to contain the entire channel design width including freeboard or the 100-year design storm, whichever is larger. The minimum width of an open channel easement shall be 15 feet. Where required, an access easement shall also be provided.

1.3.3 *Stormwater Ponds and Wetlands*

A minimum width of 25 feet shall be provided around the 100-year flood pool connecting the tributary pipes and discharge system, as well as a 20-foot wide access easement.

1.3.4 Access Easements

Access easements shall be required to provide street access to drainage easements and right-of-way. Since every development differs in size and scope, the number and location of access easements must be determined by the Engineering Department on a case-by-case basis. The minimum width of access easements shall be 20 feet.

1.4 DRAINAGE WAYS

Storm water runoff shall not be discharged from a public drainage way onto private property within the boundaries of a development or subdivision.

Any drainage way which traverses a new development or subdivision shall be located within a public drainage easement or right-of-way.

All drainage outfalls, whether public or private, must be constructed at an elevation that allows for positive drainage onto the adjacent property.

1.5 BRIDGE DESIGN

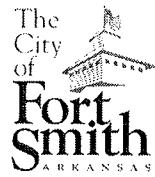
Bridge design has not been addressed and is beyond the scope of this document. Any required bridge design will be reviewed by the Engineering Department on a case-by-case basis.

1.6 DRAINAGE REPORT/PLAN REQUIREMENT CHECKLIST

The Engineer must complete the Drainage Report/Plan Requirement Checklist found in Appendix 1A, including the certification, and submit it with the drainage report and construction plans for review. The drainage report and construction plans will not be reviewed until the Drainage Report/Plan Requirement Checklist is submitted.

APPENDIX 1A

DRAINAGE REPORT/PLAN REQUIREMENT CHECKLIST



THE CITY OF FORT SMITH

DRAINAGE REPORT/PLAN REQUIREMENT CHECKLIST

Project Name: _____

Project Address: _____

Owner/Developer: _____

Engineering Firm: _____

Revision No.: _____ Date: _____

Engineer: Initial beside each number below in the space provided to acknowledge that the task is complete. If not applicable, mark "N/A" in the space. Sign the certification at the end of the document prior to submittal.

DRAINAGE REPORT:

- ____ 1. **Title and Date** – Include a title sheet which shows the project title and date of submission.
- ____ 2. **Location of Project** – Include the street address and a vicinity map.
- ____ 3. **Description of Project** – Include a brief description of the project.
- ____ 4. **Contact Information** – Include the name, address, and telephone number of the Project Owner and Developer.
- ____ 5. **Drainage Area Map** – Provide a topographic map with pre- and post-development drainage area(s) outlined.
- ____ 6. **Area Drainage Issues** – Provide a description of any known on- or off-site drainage/flooding problems.

Drainage Report/Plan Requirements Checklist

Project Name: _____

Owner/Developer: _____

Sheet 2 of 4

- _____ 7. **Written Summary of the Proposed Improvements** – Include a summary of on- and off-site improvements, any increases in flows, detention or lack of detention, and final conclusions.
- _____ 8. **Pre- and Post-Development Flowrates** – Include pre- and post-development flowrate calculations for the 10-, 25-, 50-, and 100-year storm events.
- _____ 9. **Storm Water Detention Design** – Include all calculations.
- _____ 10. **Open Channel Flow Design** – Include all calculations.
- _____ 11. **Pavement Drainage Design** – Calculations for gutter spread must be included.
- _____ 12. **Culvert Design** – All calculations (both inlet and outlet control) must be included.
- _____ 13. **Inlet Design** – Capture efficiency calculations must be included.
- _____ 14. **Storm Sewer Design** – All storm sewer design and hydraulic grade line calculations must be included.
- _____ 15. **100-Year Water Surface Elevation and Minimum Floor Elevation** – Calculations must be included for the water surface elevation resulting from the 100-year storm for all overland flow, including flow in the streets, parking lots, swales, and between lots. Minimum floor elevations must also be included. Minimum floor elevations shall be one foot above the calculated 100-year water surface elevation of open channels, swales, or overland flow.
- _____ 16. **Federal and State Requirements** – Include copies of documents which show compliance with all applicable federal and state requirements (Corps 404 Permit, ADEQ Notice of Intent, FEMA CLOMR, etc.).
- _____ 17. **Certification by Registered Professional Engineer** – The title sheet must be sealed, signed, and dated by a Professional Engineer registered in the state of Arkansas.

Drainage Report/Plan Requirements Checklist

Project Name: _____

Owner/Developer: _____

Sheet 3 of 4

PLAN REQUIREMENTS:

1. **Location of Project** – Include a vicinity map.
2. **Plan and Profile Views of All Proposed Improvements** – Plan and profile views must show the location, size, flowline elevations, gradients, materials, boring information and rock elevations (where applicable), and depths and sizes of adjacent or crossing utilities and structures.
3. **North Arrow and Scale** – Include a north arrow and scale on every applicable sheet.
4. **Bench Mark** – At least two permanent bench marks must be established and shown on the plans.
5. **Right-of-Way** – Plans must show the existing and proposed right-of-way and easements.
6. **Existing Structures and Utilities** – Plans must show the location of all existing structures, streets, driveways, storm drains, fences, trees, landscaping, utilities, and other features within 25 feet of the proposed improvements.
7. **Cross Sections** – Provide cross sections at a maximum of 50 foot intervals along the centerline of proposed improvements for a minimum width of 50 feet. Cross sections must show surface elevations, flowline elevations and sizes of all proposed improvements, and flowline elevations and sizes of all crossing or adjacent utilities or structures.
8. **Stationing** – Stationing shall be provided along the centerline of the proposed improvements.
9. **Details** – Provide details on the plans for any structure requiring special design and not included in the City of Fort Smith Standard Drawings.
10. **Floodplain and Floodway** – FEMA regulated floodplain and floodway boundaries must be shown on the plans.

Drainage Report/Plan Requirements Checklist

Project Name: _____

Owner/Developer: _____

Sheet 4 of 4

- 11. 100-Year Water Surface Elevation and Minimum Floor Elevation** – The water surface elevation resulting from the 100-year storm for all overland flow, including flow in the streets, parking lots, swales, and between lots, shall be shown on the plans. Minimum floor elevations shall be one foot above the calculated 100-year water surface elevation of open channels, swales, or overland flow.
- 12. Erosion and Sediment Control Plan (SWPPP); Grading Plan (Site Plan); Fill and Grading Permit** – An Erosion and Sediment Control Plan and Grading Plan must be included in the plans. The Fill and Grading Permit application must also be submitted for review and approval.

CERTIFICATION:

I hereby certify that the drainage report and accompanying plans for the project referenced above have been prepared in accordance with the requirements of the City of Fort Smith.

Engineer's Signature

Engineer's Printed Name

CHAPTER 2 – HYDROLOGY

2.1 GENERAL

Hydrology is generally defined as a science that addresses the interrelationship between water on and under the earth and in the atmosphere. For this manual, hydrology will address estimating flood magnitudes as the result of precipitation. In the design of drainage structures, floods are usually considered in terms of peak runoff or discharge in cubic feet per second (ft^3/s) and hydrographs as discharge per time. For structures that are designed to control the volume of runoff (e.g., detention storage facilities) or where flood routing through culverts is used, then the entire discharge hydrograph will be of interest.

2.2 DESIGN FLOW RATES

When designing drainage facilities, a design storm of a given return period is used to develop a design flow rate. For the given roadway classification, public drainage facilities within the City of Fort Smith shall be designed for the return period specified in the Table 2-1 below:

TABLE 2-1. Design Storm Selection Guidelines

Drainage Facility/Classification	Exceedence Probability	Return Period
Channels:		
All Classifications	4%	25-yr
Culverts:		
Major and Minor Arterial	2%	50-yr
All Other Classifications	4%	25-yr
Storm Drains:		
Residential	10%	10-yr
Residential Collector	10%	10-yr
Residential Collector (Restricted Parking)	10%	10-yr
Major Collector	4%	25-yr
Minor Arterial	2%	50-yr
Major Arterial	2%	50-yr
Boulevard	2%	50-yr
Industrial	4%	25-yr
All Other Systems	10%	10-yr

Provisions shall be made in drainage facilities to safely transmit the overflow from the 100-year storm event without flooding houses, buildings, structures, etc., and to provide for the health, safety, and welfare of persons and their property.

2.3 TIME OF CONCENTRATION

The time of concentration, which is denoted as t_c , is defined as the time required for a particle of water to flow from the hydraulically most distant point in the watershed to the outlet or design point. Factors that affect the time of concentration are the length of flow, the slope of the flow path and the roughness of the flow path. For flow at the upper reaches of a watershed, rainfall characteristics, most notably the intensity, may also influence the velocity of the runoff.

Various methods can be used to estimate the time of concentration of a watershed. When selecting a method to use in design, it is important to select a method that is appropriate for the flow path. Some estimation methods were designed and calibrated to be used for an entire watershed. These methods have t_c as the dependent variable. Other methods are intended for one segment of the principal flow path and produce a flow velocity that can be used with the length of that segment of the flow path to compute the travel time on that segment. With this method, the time of concentration equals the sum of the travel times on each segment of the principal flow path.

In classifying these methods so that the proper method can be selected, it is useful to describe the segments of flow paths. Sheet flow occurs in the upper reaches of a watershed. Such flow occurs over short distances and at shallow depths prior to the point where topography and surface characteristics cause the flow to concentrate in rills and swales. The depth of such flow is usually 0.8 in to 1.2 in or less. Concentrated flow is runoff that occurs in rills and swales and has depths on the order of 1.5 in to 4.0 in. Part of the principal flow path may include pipes or small streams. The travel time through these segments would be computed separately. Velocities in open channels are usually determined assuming bank-full depths.

2.3.1 *Sheet-Flow Travel Time*

Sheet flow is a shallow mass of runoff on a plane surface with the depth uniform across the sloping surface. Typically, flow depths will not exceed 2 in. Such flow occurs over relatively short distances. Sheet flow rates are commonly estimated using a version of the kinematic wave equation. The original form of the kinematic wave time of concentration is:

$$t_c = \frac{0.93}{I^{0.4}} \left(\frac{nL}{\sqrt{S}} \right)^{0.6} \quad (2.1)$$

in which t_c is the time of concentration (min), n is the roughness coefficient, L is the flow length (ft), I is the rainfall intensity (in./h) for a storm that has a return period T and duration of t_c (min), and S is the slope of the surface in ft/ft. Values of n can be obtained from Table 2-2.

The maximum allowable length for sheet flow shall be 100 feet, unless there is documented engineering justification to use a longer length. In no instance shall the length used exceed 300 feet.

TABLE 2-2. Roughness Coefficients (Manning's n) for Sheet Flow (AASHTO)

Surface Description	n ¹
Smooth surfaces (concrete, asphalt, gravel, bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20 percent	0.06
Residue cover > 20 percent	0.17
Grasses:	
Short grass prairie	0.15
Dense grasses	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods: ²	
Light underbrush	0.40
Dense underbrush	0.80

¹The n values are a composite of information compiled in Reference (3).

²When selecting n, consider cover to a height of about 1 in. This is the only part of the plant cover that will obstruct sheet flow.

Some hydrologic design methods, such as the Rational method, assume that the storm duration equals the time of concentration. Thus, the time of concentration is entered into the IDF curve to find the design intensity. However, for Equation 2.1, i depends on t_c and t_c is not initially known. Therefore, the computation of t_c is an iterative process. An initial estimate of t_c is assumed and used to obtain i from the intensity-duration-frequency curve for the locality. The t_c is computed from Equation 2.1 and used to check the initial value of i . If they are not the same, then the process is repeated until two successive t_c estimates are the same.

2.3.2 Velocity Method

The velocity method can be used to estimate travel times for sheet flow, shallow concentrated flow, pipe flow, or channel flow. It is based on the concept that the travel time (T_t) for a flow segment is a function of the length of flow (L) and the velocity (V):

$$T_t = \frac{L}{60V} \quad (2.2)$$

in which T_t , L, and V have units of minutes, feet, and feet/second, respectively. The travel time is computed for the principal flow path. Where the principal flow path consists of segments that have different slopes or land covers, the principal flow path should be divided into segments and Equation 2.2 used for each flow segment. The time of concentration is then the sum of travel times:

$$t_c = \sum_{i=1}^k T_{ti} = \sum_{i=1}^k \left(\frac{L_i}{60V_i} \right) \quad (2.3)$$

in which k is the number of segments and the subscript i refers to the flow segment.

The velocity of Equation 2.2 is a function of the type of flow (overland, sheet, rill and gully flow, channel flow, pipe flow), the roughness of the flow path, and the slope of the flow path. Some methods also include a rainfall index such as the 2-yr, 24-h rainfall depth. A number of methods have been developed for estimating the velocity.

After short distances, sheet flow tends to concentrate in rills and then gullies of increasing proportions. Such flow is usually referred to as shallow concentrated flow. The velocity of such flow can be estimated using an empirical relationship between the velocity and the slope:

$$V = kS^{0.5} \quad (2.4)$$

in which V is the velocity (ft/s) and S is the slope (%). The value of k is a function of the land cover, with values for selected land covers given in Table 2-3.

TABLE 2-3. Intercept Coefficients for Velocity vs. Slope Relationship of Equation 2.4

k	Land Cover/Flow Regime
0.249	Forest with heavy ground litter; hay meadow (overland flow)
0.499	Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)
0.699	Short grass pasture (overland flow)
0.899	Cultivated straight row (overland flow)
1.001	Nearly bare and untilled (overland flow); alluvial fans in western mountain regions
1.499	Grassed waterway (shallow concentrated flow)
1.611	Unpaved (shallow concentrated flow)
2.031	Paved area (shallow concentrated flow); small upland gullies

2.3.3 *Open Channels*

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs or where blue lines (indicating streams) appear on USGS quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull condition.

Manning's equation is:

$$V = \frac{1.486 R^{2/3} S^{1/2}}{n} \quad (2.5)$$

where:

V = average velocity, ft/s

R = hydraulic radius, ft (equal to A/WP)

A = cross sectional flow area, ft²

WP = wetted perimeter, ft

S = slope of the hydraulic grade line, ft/ft

n = Manning's roughness coefficient

After average velocity is computed using Equation 2.5, T_t for the channel segment can be estimated using Equation 2.2.

2.4 HYDROLOGIC METHODS

There are numerous methods of rainfall computations on which the design of storm drainage and flood control systems are based. The methods to be used in the City of Fort Smith and the circumstances for their use are listed below:

- The Rational Method shall only be used for drainage areas less than 200 acres. If a watershed or basin involves a design time of concentration in excess of 30 minutes, then the applicability of the Rational Method must be checked.
- The NRCS TR-55 Tabular Hydrograph Method shall only be used for drainage areas between 100 and 2,000 acres.
- Suitable computer programs (e.g., HYDRO, HEC-1, HEC-HMS and TR-20) may be used to facilitate tedious hydrologic calculations. Programs must be approved by the Engineering Department.
- The 100-year discharges specified in the FEMA flood insurance study shall be used to analyze the impacts of a proposed crossing on a regulatory floodway. However, if these discharges are deemed to be outdated, the discharges based on current methods may be used subject to receipt of necessary regulatory approvals.
- Other methods may be used for drainage areas in excess of 2,000 acres, subject to approval by the Engineering Department.

2.4.1 *Rational Method*

The Rational method may be used for estimating the design storm peak runoff for areas as large as 200 acres. The Rational formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient and mean rainfall intensity for a duration equal to the time of concentration (the time required for water to flow from the most

remote point of the basin to the location being analyzed). The Rational formula is expressed as follows:

$$Q = CIA \quad (2.7)$$

where:

Q is defined as the peak rate of runoff in cubic feet per second. Actually, Q is in units of acre-inches per hour, but calculator results differ from cubic feet by less than one percent. Since the difference is so small, the Q value calculated by the equation is universally taken as cubic feet per second, or *CFS*.

C is the dimensionless coefficient of runoff represented in the ratio of the amount of runoff to the amount of rainfall.

I is the average intensity of rainfall in inches per hour for a period of time equal to the critical time of full contribution of the drainage area under consideration. This critical time for full contribution is commonly referred to as time of concentration.

A is the area in acres that contributes to runoff at the point of design or the point under consideration.

Basic assumptions associated with use of the Rational Method are as follows:

- The computed peak rate of runoff to the design point is the function of the average rainfall rate during the time of concentration to that point.
- The time of concentration is the critical value in determining the design rainfall intensity and is equal to the time required for water to flow from the hydraulically most distant point in the watershed to the point of design.
- The ratio of runoff to rainfall, C , is uniform during the entire duration of the storm event.
- The rate of rainfall or rainfall intensity, I , is uniform for the entire duration of the storm event and is uniformly distributed over the entire watershed area.

2.4.1.1 Infrequent Storms

The coefficients given in Tables 2-5 and 2-6 are applicable for storms of 5-year to 10-year frequencies. Less frequent, higher intensity storms will require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on runoff. See Reference (4). The adjustment of the Rational method for use with major storms can be made by multiplying the right side of the Rational formula by a frequency factor C_f . The Rational formula now becomes:

$$Q = CC_f IA \quad (2.8)$$

C_f values are listed in Table 2-4.

TABLE 2-4. Frequency Factors for Rational Formula

Recurrence Interval (years)	C_f
25	1.1
50	1.2
100	1.25

The product of C_f times C shall not exceed 1.0.

**TABLE 2-5. Recommended Coefficient of Runoff Values
(For Various Selected Land Uses)**

Description of Area	Runoff Coefficients
Business: Downtown areas	0.70–0.95
Neighborhood areas	0.50–0.70
Residential: Single-family areas	0.30–0.50
Multi units, detached	0.40–0.60
Multi units, attached	0.60–0.75
Suburban	0.25–0.40
Residential (2.5 ac lots or more)	0.30–0.45
Apartment dwelling areas	0.50–0.70
Industrial: Light areas	0.50–0.80
Heavy areas	0.60–0.90
Parks, cemeteries	0.10–0.25
Playgrounds	0.20–0.40
Railroad yard areas	0.20–0.40
Unimproved areas	0.10–0.30

Source: HDS No. 2 (1).

TABLE 2-6. Coefficients for Composite Runoff Analysis

Surface	Runoff Coefficients
Streets: Asphalt	0.70–0.95
Concrete	0.80–0.95
Drives and walks	0.75–0.85
Roofs	0.75–0.95

Source: HDS No. 2 (1).

2.4.1.2 Runoff Coefficient

The runoff coefficient, C, is the variable of the Rational method least amenable to precise determination and requires the judgment and understanding of the designer. Although engineering judgment will always be required in the selection of runoff coefficients, a typical coefficient represents the integrated effects of many drainage basin parameters; the following discussion considers only the effects of land use.

Two methods for determining the runoff coefficient are presented based on land use (Table 2-5) and a composite coefficient for complex watersheds (Table 2-6).

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surface in the drainage area. Composites can be made with Tables 2-5 and 2-6. The composite procedure can be applied to an entire drainage area or to typical “sample” blocks as a guide to the selection of reasonable values of the coefficient for an entire area.

2.4.1.3 Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate (in./h) for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the drainage area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves. Curves for use within the City of Fort Smith are given in Appendix 2A.

2.4.1.4 Drainage Area

The drainage area (A) is measured in acres when using the Rational Method. Drainage areas should be delineated and calculated using 2-foot contour information. Such information may be obtained through the Engineering Department.

2.4.1.5 Example Problem – Rational Method

Following is an example problem that illustrates the application of the Rational method to estimate peak discharges.

Preliminary estimates of the maximum rate of runoff are needed at the inlet to a culvert for a 10-yr and 50-yr return period.

Site Data

From a topographic map and field survey, the area of the drainage basin upstream from the point in question is found to be 5 ac. In addition, the following data were measured:

Length of overland flow = 265 ft
Length of grassed waterway = 65 ft

Average overland slope = 0.3 percent
Average grassed waterway slope = 0.5 percent

Land Use

From existing land-use maps, land use for the drainage basin was estimated to be:

Residential (1.2-ac lots) = 80 percent
Playground = 20 percent

Step 1 Calculate Time of Concentration

For overland flow (short grass pasture) from Table 2-3, k = 0.699:

$$V = (0.699)(0.3)^{0.5} = 0.4 \text{ ft/s}$$

$$T_t = \frac{265 \text{ ft}}{(0.4 \text{ ft/s})(60 \text{ s/min})} = 11.1 \text{ min}$$

For grassed waterway (shallow concentrated flow) from Table 2-3, k = 1.499:

$$V = (1.499)(0.5)^{0.5} = 1.1 \text{ ft/s}$$

$$T_t = \frac{65 \text{ ft}}{(1.1 \text{ ft/s})(60 \text{ s/min})} = 1.0 \text{ min}$$

$$T_c = T_t (\text{overland flow}) + T_t (\text{grassed waterway}) = 12.1 \text{ min}$$

Step 2 Determine Rainfall Intensity

From Appendix 2B with duration equal to 12.1min:

$$\begin{aligned} I_{10} &= 5.8 \text{ in./hour} \\ I_{50} &= 7.3 \text{ in./hour} \end{aligned}$$

Step 3 Determine C, Runoff Coefficient

A weighted runoff coefficient C for the total drainage area is determined in the following table by utilizing the values from Table 2-6

:

Land Use	(1) Percent of Total Land Area	(2) Runoff Coefficient	(3) Weighted Runoff Coefficient ¹
Residential (1.2 ac lots)	80%	0.3	0.24
Playground	20%	0.2	0.04
Total Weighted Runoff			0.28
¹ Column 3 equals Column 1 multiplied by Column 2.			

Step 4 Determine Peak Runoff

From the Rational equation:

$$Q_{10} = CIA = (0.28)(5.8 \text{ in./h})(5.0 \text{ ac}) = 8 \text{ ft}^3/\text{s}$$

$$Q_{50} = C_f CIA = (1.2)(0.28)(7.3 \text{ in./h})(5.0 \text{ ac}) = 12 \text{ ft}^3/\text{s}$$

Note: $C_f = 1.2$ from Table 2-4.

These are the estimates of peak runoff for a 10- and 50-yr design storm for the given basin.

2.4.2 NRCS TR-55, Tabular Hydrograph Method

The NRCS tabular method is a synthetic hydrograph method developed specifically for use in urbanized and urbanizing areas. This method is similar to the Rational Method in that runoff is directly related to rainfall amounts through use of Runoff Curve Numbers. The basic equation used with the tabular method is also very similar to the one used for the Rational Method:

$$q = q_t A_m Q \quad (2.9)$$

where:

q = hydrograph coordinate (ft^3/s) at hydrograph time t

q_t = tabular hydrograph unit discharge (csm/in.)

A_m = drainage area of individual subarea (mi^2)

Q = accumulated direct runoff (in.)

Note: $\text{csm/in.} = \text{cubic feet per second per square mile per inch of runoff}$

Hydrograph coordinates are computed from the hydrograph distribution data in the TR-55 Manual. A coordinated value is computed for each time shown in the distribution data. The calculated q results, when plotted against the corresponding times, constitute the runoff hydrograph.

The tabular method is useful in analyzing watersheds involving several subareas with complex runoff patterns. The method is most useful in analyzing changes in runoff volume due to development and in evaluating runoff control measures. The NRCS tabular method as described here shall be used in all cases where watershed problems involve two or more interacting subareas.

2.4.2.1 Accumulated Direct Runoff

A relationship between accumulated rainfall and accumulated runoff was derived by NRCS from experimental plots for numerous soils and vegetative cover conditions. Data for land-treatment measures (e.g., contouring, terracing) from experimental watersheds were included. The equation was developed mainly for small watersheds for which only daily rainfall and watershed data are ordinarily available. It was developed from recorded storm data that included the total amount of rainfall in a calendar day but not its distribution with respect to time. The NRCS runoff equation is therefore a method of estimating direct runoff from a 24-hour or 1-day storm rainfall. The equation is:

$$Q = (P - I_a)^2 / (P - I_a + S) \quad (2.10)$$

where:

Q = accumulated direct runoff (in.)

P = accumulated rainfall (potential maximum runoff) (in.)

I_a = initial abstraction including surface storage, interception and infiltration prior to runoff (in.)

S = potential maximum retention (in.)

The relationship between I_a and S was developed from experimental watershed data. It removes the necessity for estimating I_a for common usage. The empirical relationship used in the NRCS runoff equation is:

$$I_a = 0.2S \quad (2.11)$$

Substituting $0.2S$ for I_a in Equation 2.10, the NRCS rainfall-runoff equation becomes:

$$Q = (P - 0.2S)^2 / (P + 0.8S) \quad (2.12)$$

The accumulated rainfall, P, is based on the 24-hour rainfall amount for the design recurrence interval of interest. The 24-hour rainfall amounts for the City of Fort Smith are taken from the U.S. Weather Bureau's *Technical Paper No. 40* and are listed below:

10-year frequency	P = 6.3 in.
25-year frequency	P = 7.3 in.
50-year frequency	P = 8.2 in.
100-year frequency	P = 9.2 in.

The potential maximum retention, S, is related to the soil and cover conditions of the watershed through the NRCS runoff curve number, CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = (1000 / CN) - 10 \quad (2.13)$$

The runoff curve number is discussed in greater detail in Section 2.4.2.2 below. Typical values for runoff curve numbers are shown in Table 2-8.

Figure 2-1 shows a graphical solution of equation 2.12, which enables the precipitation excess from a storm to be obtained if the accumulated rainfall and watershed curve number are known.

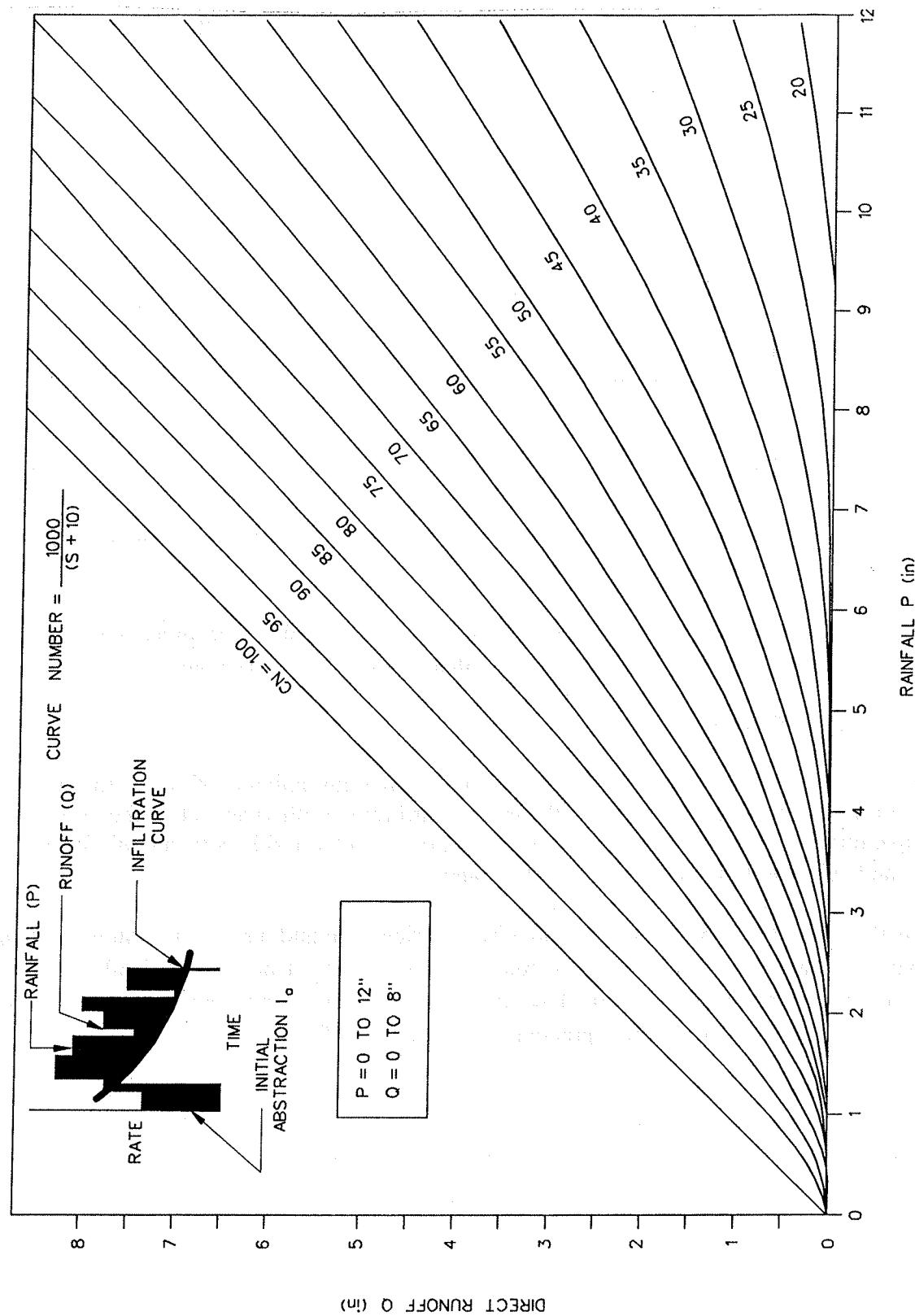
2.4.2.2 Runoff Factor

Often times, runoff is referred to as rainfall excess or effective rainfall, all defined as the amount by which rainfall exceeds the capability of the land to infiltrate or otherwise retain the rainwater. The principal physical watershed characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types and land slope.

Land use is the watershed cover, and it includes both agricultural and nonagricultural uses. Items such as type of vegetation, water surfaces, roads and roofs are all part of the land use. Land treatment applies mainly to agricultural land use, and it includes mechanical practices (e.g., contouring, terracing) and management practices (e.g., rotation of crops).

NRCS uses a combination of soil conditions and land use (ground cover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area when the soil is not frozen. The higher the CN, the higher the runoff potential.

FIGURE 2-1. NRCS Relation Between Direct Runoff, Curve Number and Precipitation



Soil properties influence the relationship between runoff and rainfall because soils have differing rates of infiltration. Infiltration is the movement of water through the soil surface into the soil. Based on infiltration rates, NRCS has divided soils into four hydrologic soil groups as follows:

- Group A Soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well-drained sands and gravels.
- Group B Soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures.
- Group C Soils having a moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.
- Group D Soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high watertables, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious parent material.

Soil classifications important to the City of Fort Smith are given in Appendix 2B.

Consideration should be given to the effects of urbanization on the natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes should be made in the soil group selected. Also, runoff curve numbers vary with the antecedent soil moisture conditions, defined as the amount of rainfall occurring in a selected period preceding a given storm. In general, the greater the antecedent rainfall, the more direct runoff there is from a given storm. A five-day period is used as the minimum for estimating antecedent moisture conditions. Antecedent soil moisture conditions also vary during a storm; heavy rain falling on a dry soil can change the soil moisture condition from dry to average to wet during the storm period.

Table 2-7 presents the NRCS curve number values for the different land uses, treatments and hydrologic conditions; separate values are given for each soil group. For example, the CN for a wooded area with good cover and soil group B is 55; for soil group C, the CN would increase to 70. If the cover (on soil group B) is poor, the CN will be 66.

Table 2-7 is based on an average antecedent moisture condition; i.e., soils that are neither very wet nor very dry when the design storm begins. Curve numbers should be selected only after a field inspection of the watershed and a review of zoning and soil maps. Table 2-8 gives conversion factors to convert average curve numbers to wet curve numbers. **Only curve numbers for wet conditions shall be used in the design of storm drainage systems.**

**TABLE 2-7. Runoff Curve Numbers (Average Watershed Condition, $I_a = 0.2S$)
(After Reference (4))**

Cover Type	Curve Numbers for Hydrologic Soil Group				
	A	B	C	D	
Fully developed urban areas ^a (vegetation established)					
Lawns, open spaces, parks, golf courses, cemeteries, etc.					
Good condition; grass cover on 75% or more of the area	39	61	74	80	
Fair condition; grass cover on 50% to 75% of the area	49	69	79	84	
Poor condition; grass cover on 50% or less of the area	68	79	86	89	
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	98	98	98	98	
Streets and roads					
Paved with curbs and storm sewers (excluding right-of-way)	98	98	98	98	
Gravel (including right-of-way)	76	85	89	91	
Dirt (including right-of-way)	72	82	87	89	
Paved with open ditches (including right-of-way)	83	89	92	93	
Cover Type	Hydrologic Condition ^d	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Western desert urban areas:	Average % impervious ^b				
Commercial and business areas	85	89	92	94	95
Industrial districts	72	81	88	91	93
Row houses, town houses, and residential with lots sizes $\frac{1}{8}$ ac or less	65	77	85	90	92
Residential: average lot size					
$\frac{1}{4}$ ac	38	61	75	83	87
$\frac{1}{3}$ ac	30	57	72	81	86
$\frac{1}{2}$ ac	25	54	70	80	85
1 ac	20	51	68	79	84
2 ac	12	46	65	77	82
Western desert urban areas:					
Natural desert landscaping (pervious areas only)		63	77	85	88

Artificial desert landscaping (impervious weed barrier, desert shrub with 1-in. to 2-in. sand or gravel mulch and basin borders)		96	96	96	96		
Developing urban areas ^c (no vegetation established) Newly graded area		77	86	91	94		
Cultivated Agricultural Land: Fallow							
Straight row or bare soil		77	86	91	94		
Conservation tillage	Poor	76	85	90	93		
	Good	74	83	88	90		
Row crops	Straight row	Poor	72	81	88	91	
		Good	67	78	85	89	
	Conservation tillage	Poor	71	80	87	90	
		Good	64	75	82	85	
	Contoured	Poor	70	79	84	88	
		Good	65	75	82	86	
	Contoured and tillage	Poor	69	78	83	87	
		Good	64	74	81	85	
	Contoured and terraces	Poor	66	74	80	82	
		Good	62	71	78	81	
	Contoured and terraces and conservation tillage	Poor	65	73	79	81	
		Good	61	70	77	80	
Small grain	Straight row	Poor	65	76	84	88	
		Good	63	75	83	87	
Close-seeded or broadcast legumes or rotation meadows ^e	Conservation tillage	Poor	64	75	83	86	
		Good	60	72	80	84	
	Contoured	Poor	63	74	82	85	
		Good	61	73	81	84	
	Contoured and tillage	Poor	62	73	81	84	
		Good	60	72	80	83	
	Contoured and terraces	Poor	61	72	79	82	
		Good	59	70	78	81	
	Contoured and terraces and conservation tillage	Poor	60	71	78	81	
		Good	58	69	77	80	
	Straight row	Poor	66	77	85	89	
		Good	58	72	81	85	
	Contoured	Poor	64	75	83	85	
		Good	55	69	78	83	
	Contoured and terraces	Poor	63	73	80	83	
		Good	57	67	76	80	
Noncultivated agricultural land							
Pasture or range	No Mechanical treatment ^f	Poor	68	79	86	89	
		Fair	49	69	79	84	
		Good	39	61	74	80	
	Contoured	Poor	47	67	81	88	
		Fair	25	59	75	83	
		Good	6	35	70	79	
Meadow—continuous grass, protected from grazing and generally mowed for hay							
Forestland—grass or orchards—evergreen or Deciduous		Poor	55	73	82	86	
		Fair	44	65	76	82	
		Good	32	58	72	79	
		Poor	48	67	77	83	

Brush—brush-weed-grass mixture with brush the major element ^g	Fair	35	56	70	77
	Good	30 ^f	48	65	73
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 ^f	55	70	77
Woods—grass combination (orchard or tree farm) ^h	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Farmsteads		59	74	82	86
Forest-range					
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon—juniper - pinyon, juniper, or both grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sage-grass	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

^a For land uses with impervious areas, curve numbers are computed assuming that 100 percent of runoff from impervious areas is directly connected to the drainage system. Pervious areas (lawn) are considered to be equivalent to lawns in good condition and the impervious areas have a CN of 98.

^b Includes paved streets.

^c Use for the design of temporary measures during grading and construction. Impervious area percent for urban areas under development vary considerably. The user will determine the percent impervious. Then using the newly graded area CN, the composite CN can be computed for any degree of development.

^d For conservation tillage poor hydrologic condition, 5 to 20 percent of the surface is covered with residue (less than 750 lb/ac row crops or 300 lb/ac small grain). For conservation tillage good hydrologic condition, more than 20 percent of the surface is covered with residue (greater than 750 lb/ac row crops or 300 lb/ac small grain).

^e Close-drilled or broadcast.

– For noncultivated agricultural land:

- Poor hydrologic condition has less than 25 percent ground cover density.
- Fair hydrologic condition has between 25 percent and 50 percent ground cover density.
- Good hydrologic condition has more than 50 percent ground cover density.

– For forest-range:

- Poor hydrologic condition has less than 30 percent ground cover density.
- Fair hydrologic condition has between 30 percent and 70 percent ground cover density.
- Good hydrologic condition has more than 70 percent ground cover density.

^f Actual curve number is less than 30: Use CN = 30 for runoff computations.

^g CNs shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

- ^h Poor: < 50 percent ground cover.
 Fair: 50 to 75 percent ground cover.
 Good: > 75 percent ground cover.
- ⁱ Poor: < 50 percent ground cover or heavily grazed with no mulch.
 Fair: 50 to 75 percent ground cover and not heavily grazed.
 Good: > 75 percent ground cover and lightly or only occasionally grazed.

TABLE 2-8. Conversion from Average Antecedent Moisture Conditions to Dry and Wet Conditions

CN For Average Conditions	CN For Wet Conditions
100	100
95	98
90	96
85	94
80	91
75	88
70	85
65	82
60	78
55	74
50	70
45	65
40	60
35	55
30	50
25	43
15	30
5	13

Source: Reference (2).

2.4.2.3 Estimation of CN Values for Urban Land Uses

The CN table (Table 2-7) includes CN values for a number of urban land uses. For each of these, the CN is based on a specific percentage of imperviousness. For example, the CN values for commercial land use are based on an imperviousness of 85 percent. Curve numbers for other percentages of imperviousness can be computed using a weighted CN approach, with a CN of 98 used for the impervious areas and the CN for open space (good condition) used for the pervious portion of the area. Thus, CN values of 39, 61, 74, and 80 are used for hydrologic soil groups A, B, C, and D, respectively. These are the same CN values for pasture in good condition. Thus, the following equation can be used to compute a weighted CN:

$$CN_w = CN_p(1-f) + f(98) \quad (2.14)$$

in which f is the fraction (not percentage) of imperviousness. To show the use of Equation 2.14, the CN values for commercial land use with 85 percent imperviousness are:

$$\text{A soil: } 39(0.15) + 98(0.85) = 89$$

$$\text{B soil: } 61(0.15) + 98(0.85) = 92$$

$$\text{C soil: } 74(0.15) + 98(0.85) = 94$$

$$\text{D soil: } 80(0.15) + 98(0.85) = 95$$

These are the same values shown in Table 2-7.

2.4.2.4 Parameter I_a/P

I_a/P is a parameter that is necessary to determine the tabular hydrograph unit discharges, q_t , from the tables shown in Appendix 2C. I_a denotes the initial abstraction, and P is the 24-hour rainfall depth for a selected return period. The I_a/P value can be obtained from Table 2-10 for a given CN and P . For a given 24-h rainfall distribution, I_a/P represents the fraction of rainfall that must occur before runoff begins.

2.4.2.5 Limitations of the NRCS TR-55, Tabular Hydrograph Method

The Tabular Hydrograph method does have several limitations. This method shall not be used if: T_t is greater than 3 hours, T_c is greater than 2 hours, drainage areas of individual subareas differ by a factor of 5 or more, the entire composite flood hydrograph or entire runoff volume is required for detailed flood routings, or the time of peak discharge must be more accurate than that obtained through the Tabular Hydrograph method. If any of these conditions apply, a hydrograph method such as TR-20 shall be used (3).

TABLE 2-10. I_a/P for Selected Rainfall Depths and Curve Numbers

Rainfall (in.)	Curve Number											
	40	45	50	55	60	65	70	75	80	85	90	95
0.4	*	*	*	*	*	*	*	*	*	*	*	0.27
0.8	*	*	*	*	*	*	*	*	*	0.45	0.28	0.13
1.2	*	*	*	*	*	*	*	*	0.42	0.3	0.19	+
1.6	*	*	*	*	*	*	*	0.42	0.32	0.22	0.14	+
2	*	*	*	*	*	*	0.44	0.34	0.25	0.18	0.11	+
2.4	*	*	*	*	*	0.46	0.36	0.28	0.21	0.15	+	+
2.8	*	*	*	*	0.48	0.39	0.31	0.24	0.18	0.13	+	+
3.1	*	*	*	*	0.42	0.34	0.27	0.21	0.16	0.11	+	+
3.5	*	*	*	0.46	0.38	0.3	0.24	0.19	0.14	0.1	+	+
3.9	*	*	*	0.42	0.34	0.27	0.22	0.17	0.13	+	+	+
4.3	*	*	0.46	0.38	0.31	0.25	0.2	0.15	0.12	+	+	+
4.7	*	*	0.42	0.35	0.28	0.23	0.18	0.14	0.11	+	+	+
5.1	*	0.48	0.39	0.32	0.26	0.21	0.17	0.13	0.1	+	+	+
5.5	*	0.44	0.36	0.3	0.24	0.2	0.16	0.12	+	+	+	+
5.9	*	0.41	0.34	0.28	0.23	0.18	0.15	0.11	+	+	+	+
6.3	0.48	0.39	0.32	0.26	0.21	0.17	0.14	0.11	+	+	+	+
6.7	0.45	0.37	0.3	0.24	0.2	0.16	0.13	0.1	+	+	+	+
7.1	0.42	0.34	0.28	0.23	0.19	0.15	0.12	+	+	+	+	+
7.5	0.4	0.33	0.27	0.22	0.18	0.14	0.11	+	+	+	+	+
7.9	0.38	0.31	0.25	0.21	0.17	0.14	0.11	+	+	+	+	+
8.3	0.36	0.3	0.24	0.2	0.16	0.13	0.1	+	+	+	+	+
8.7	0.35	0.28	0.23	0.19	0.15	0.12	0.1	+	+	+	+	+
9.1	0.33	0.27	0.22	0.18	0.15	0.12	+	+	+	+	+	+
9.4	0.32	0.26	0.21	0.17	0.14	0.11	+	+	+	+	+	+
9.8	0.3	0.25	0.2	0.17	0.14	0.11	+	+	+	+	+	+
10.2	0.29	0.24	0.2	0.16	0.13	0.11	+	+	+	+	+	+
10.6	0.28	0.23	0.19	0.15	0.13	0.1	+	+	+	+	+	+
11	0.27	0.22	0.18	0.15	0.12	0.1	+	+	+	+	+	+
11.4	0.26	0.21	0.18	0.14	0.12	+	+	+	+	+	+	+
11.8	0.25	0.21	0.17	0.14	0.11	+	+	+	+	+	+	+
12.2	0.25	0.2	0.16	0.13	0.11	+	+	+	+	+	+	+
12.6	0.24	0.19	0.16	0.13	0.11	+	+	+	+	+	+	+
13	0.23	0.19	0.15	0.13	0.1	+	+	+	+	+	+	+
13.4	0.22	0.18	0.15	0.12	0.1	+	+	+	+	+	+	+
13.8	0.22	0.18	0.15	0.12	0.1	+	+	+	+	+	+	+
14.2	0.21	0.17	0.14	0.12	+	+	+	+	+	+	+	+
14.6	0.21	0.17	0.14	0.11	+	+	+	+	+	+	+	+
15	0.2	0.16	0.13	0.11	+	+	+	+	+	+	+	+
15.4	0.2	0.16	0.13	0.11	+	+	+	+	+	+	+	+
15.7	0.19	0.16	0.13	0.1	+	+	+	+	+	+	+	+

* $I_a/P = 0.50$ should be used.

+ $I_a/P = 0.10$ should be used.

2.4.3 Computer Methods

Suitable computer programs (such as TR-20, HEC-1, HEC-HMS, etc.) may be used to determine and route runoff hydrographs. All programs used must have approval of the Engineering Department.

2.5 REFERENCES

- (1) FHWA. *Highway Hydrology*. Hydraulic Design Series No. 2, FHWA-SA-96-067. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1996.
- (2) Soil Conservation Service. *A Method for Estimating Volume and Rate of Runoff in Small Watersheds*. Technical Publication 149. Natural Resources Conservation Service, Washington, DC, Revised April 1973.
- (3) Soil Conservation Service. *Urban Hydrology for Small Watersheds*. Technical Release No. 55, Natural Resources Conservation Service, Washington, DC, 1986.
- (4) Wright-McLaughlin Engineers. *Urban Drainage and Flood Control Criteria Manual and Handbook*. Denver Regional Council of Government in Denver, Colorado, 1969.

APPENDIX 2A

I-D-F CURVES
(Source: AHTD)

10-15-80

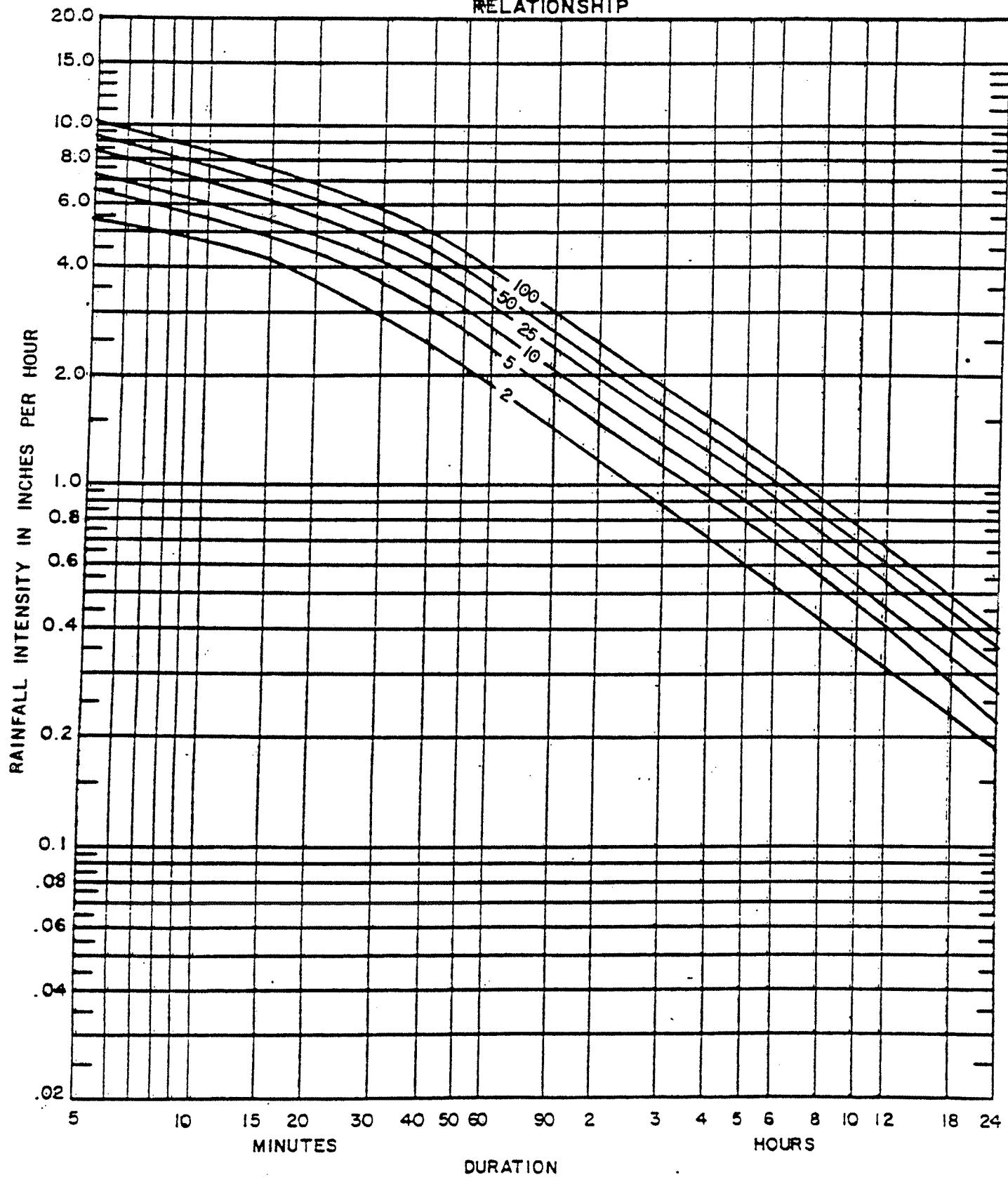
AREA IV
RAINFALL INTENSITY DURATION FREQUENCY
RELATIONSHIP

FIGURE 2A-1. Area IV Rainfall Intensity Duration Frequency Relationship

APPENDIX 2B

SOIL CLASSIFICATIONS (Source: AHTD)

Table 3-1

Soil Names and Hydrological Classification in Arkansas

Acadia D	Dunning D	Leeper D	Ramsey D
Adator D		Leesburg B	Razort B
Agnos B	Earle D	Lexington B	Rexor A
Alaga A	Egam C	Linside C	Rilla B
Allen B	Elsah B	Lily B	Roanoke D
Alligator D	Emory B	Linker B	Robinsville B
Amagon D	Enders C	Lobelville C	Roellen D
Amy D	Ennis B	Locust C	Routon D
Angie C	Estate C	Lonoke B	Ruston B
Apison B	Etowah B	Loring C	
Arkabutla C	Eutaw D	Lucy A	Sacul D
Ashton B	Eylau C	Luverne C	Saffell B
Ashwood C			Sallisaw B
Askew C	Falaya C	Mantachie C	Samba D
Avilla B	Falkner C	Marietta C	Sardis C
	Fatima B	Marvell B	Savannah C
Barling C	Fayetteville B	Mashulaville D	Sawyer C
Baxter B	Felker D	Mayes D	Secesh B
Beasley C	Foley D	Mayhew D	Sequatchie B
Beulah B	Forrestdale D	McCrory D	Sessum D
Bibb D	Fountain D	McGehee C	Sharkey D
Billyhaw D		McKamic D	Sherwood B
Blevins B	Gallion B	McLaurin B	Shubuta C
Boden C	Gasconade D	Melvin D	Sidon C
Bodine B	Gassville C	Memphis B	Sloan D
Bonn D	Geep B	Mhoon D	Smithdale B
Eosket B	Gladwater D	Miller D	Smithton D
Boswell D	Goldsboro C	Millwood D	Sogn D
Bowdre C	Goldston C	Moko C	Spadra B
Bowie B	Gore D	Monongahela C	Stanser B
Erandor B	Grenda C	Montevallo D	State B
Briley B	Grubbs D	Moreland D	Steele B
Britwater B	Guin A	Morganfield B	Steprock B
Brocket C	Guthrie D	Morse D	Sterlington B
Broseley B	Guyton D	Mountainburg D	Stough C
Brunc A		Muldrow D	Sturkie B
Bude C	Harleston C	Muskogee C	Stuttgart D
Buxin D	Hartsells B	Myatt D	Summit C
Brockwell B	Hatchie C	Nacogdoches B	Sumter C
	Hayti D	Natchez B	Susquehanna D
Caddo D	Healing B	Neila B	Taft C
Cahaba B	Hebert C	Newardk C	Talbott C
Calhoun D	Hector D	Newellton D	Taloka D
Calloway C	Henry D	Newtonia B	Terouge D
Cane C	Hillemann C	Nixa C	Tiak C
Captina C	Hollywood D	Noark B	Tichnor D
Carnasaw C	Holston B	Norfolk B	Tippah C
Carytown D	Houlka D	Norwood B	Tiptonville B
Cascilla B	Houston D	Nugent A	Toine B
Caspiana B	Huntington B	Oaklimeter C	Townley C
Catalpa C	Iberia D	Oklared B	Trebloc D
Ceda B	Iuka C	Ochlockonee B	Trinity D
Chastain D	Izagora C	Oktibbeha B	Troup A
Chennely C		Ora C	Tuckerman D
Cherokee D		Orangeburg B	Tunica D
Christian C	Jackport D	Ouachita C	Tuscumbia D
Clarksville B	Jay C	Ozan D	Tutwiler B
Clebit D	Jeanerette D	Patterson C	Una D
Cleora B	Johnsburg D	Pembroke B	Vaiden D
Collins C	Kalmia B	Peridge B	Ventris D
Commerce C	Kamie B	Perry D	
Conasauga C	Karma B	Pheba D	Wabbaseka D
Convent C	Kaufman D	Philo C	Wabeh B
Corydon D	Keo B	Pickens D	Wardell C
Coushatta B	Kiematia A	Pickwick B	Waverly D
Crevassee A	Kipling D	Pikeview B	Waynesboro B
Crowley D	Kirvin C	Pirum B	Weston D
Cuthbert C	Kobel D	Pipe E	Wickham B
	Lafe D	Protia C	Wideman A
Darco A	Lagrange D	Portland D	Wilcox D
Dardanelle B	Latanier D	Prentiss C	Wilson S
Demopolis C	Latonia B	Providence C	
Desta D	Leadvale C		
Dexter B	Leaf D		
Doniphan B			
Dubbs B			
Dundee C			

TABLE 2B-1. Names of Hydrological Classification in Arkansas

APPENDIX 2C

TABULAR HYDROGRAPH UNIT DISCHARGES
(Source: TR-55)

REFERENCES

1. J. C. G. Ruyter, *J. Phys. Chem.*, **63**, 1023 (1959); *J. Polym. Sci.*, **31**, 111 (1958).
2. J. C. G. Ruyter, *J. Phys. Chem.*, **63**, 1030 (1959); *J. Polym. Sci.*, **31**, 121 (1958).

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution

(210-VI-TR-55, Second Ed., June 1986)

TABLE 2C-1. Tabular Hydrograph Unit Discharges

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—continued

TIME (hr)	HYDROGRAPH TIME (HOURS)												IA/P = 0.10
	11.3	11.6	11.9	12.1	12.3	12.5	12.7	13.0	13.4	13.8	14.3	15.0	
0.0	50	119	176	258	448	565	483	358	270	194	137	93	60
.10	42	70	103	151	222	372	501	489	402	314	234	181	56
.20	23	39	64	90	131	192	312	438	472	425	351	273	163
.30	21	26	33	48	59	79	114	166	263	380	441	431	378
.40	20	25	32	45	54	71	99	144	224	328	404	422	392
.50	18	22	28	38	43	51	64	88	125	191	282	363	402
1.0	12	16	20	25	30	33	37	42	50	64	87	125	184
1.5	8	10	13	17	18	19	21	23	25	27	30	33	38
2.0	5	7	9	12	13	14	15	16	17	19	20	22	24
2.5	2	3	5	7	8	9	10	11	12	13	14	16	18
3.0	1	2	3	5	5	6	6	6	7	8	9	10	11
IA/P = 0.30	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
0.0	0	0	0	17	49	115	297	489	462	379	307	230	167
.10	0	0	0	0	12	37	89	228	402	442	400	338	266
.20	0	0	0	0	1	8	27	69	175	326	403	401	359
.30	0	0	0	0	1	6	20	52	134	262	356	386	368
.40	0	0	0	0	1	4	15	40	103	209	307	360	365
.50	0	0	0	0	0	0	0	0	0	0	0	0	0
.75	0	0	0	0	0	0	0	1	5	14	37	83	150
1.0	0	0	0	0	0	0	0	0	2	7	20	48	94
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0
IA/P = 0.50	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
0.0	0	0	0	0	0	10	110	206	245	208	162	137	117
.10	0	0	0	0	0	7	76	163	217	235	181	152	122
.20	0	0	0	0	0	0	52	126	187	219	218	193	145
.30	0	0	0	0	0	3	36	96	156	198	211	199	155
.40	0	0	0	0	0	0	0	0	0	0	0	0	0
.50	0	0	0	0	0	0	0	0	0	0	0	0	0
.75	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAINFALL TYPE = III	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
* * * TC = 0.2	HR *	*	*	*	*	*	*	*	*	*	*	*	*
IA/P = 0.10	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
IA/P = 0.30	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
IA/P = 0.50	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +

(210-VI-TR-56, Second Ed., June 1986)

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—continued

TRVL TIME (hr)	11.3	HYDROGRAPH TIME (HOURS)												14.3	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0							
		11.0	11.6	12.1	12.3	12.4	12.5	12.6	12.8	13.0	13.4	13.6																						
IA/P = 0.10	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	IA/P = 0.10		
0.0	25	31	44	84	124	181	287	441	498	451	358	276	204	118	87	70	63	58	54	48	44	39	34	29	24	22	20	17	14	13	11	0		
.10	22	28	37	56	74	108	156	244	375	457	453	389	314	180	113	83	69	62	57	51	41	36	31	26	23	21	18	15	13	11	0			
.20	21	27	35	53	67	94	136	208	319	411	439	406	345	212	130	91	73	64	59	52	42	36	31	26	23	21	18	15	13	11	0			
.30	19	24	30	42	49	61	91	136	181	272	365	414	409	305	190	121	87	71	63	55	49	43	38	33	27	24	21	19	15	14	11	0		
.40	18	23	29	40	46	56	74	103	153	232	321	383	400	329	217	138	96	75	65	57	50	44	38	33	28	24	21	19	15	14	11	0		
.50	16	21	26	34	38	52	67	91	132	199	280	349	383	297	196	128	91	73	60	53	46	40	35	30	25	20	17	13	11	0				
.75	14	18	23	30	33	43	52	66	91	131	187	251	347	331	260	182	126	92	68	57	49	42	36	31	26	23	21	18	15	14	11	0		
1.0	11	15	18	23	25	28	30	33	38	44	54	71	98	192	296	234	204	154	94	69	55	45	40	34	29	25	22	17	15	12	0			
IA/P = 0.30	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	IA/P = 0.30		
0.0	1.5	7	9	12	15	17	18	21	23	25	27	30	33	45	75	137	222	287	300	233	149	84	57	47	40	35	30	25	20	16	13	7	0	
2.0	4	6	8	11	12	13	14	15	16	17	19	20	22	26	33	46	76	131	201	278	258	165	85	57	46	40	34	29	22	17	13	7	0	
2.5	2	3	5	7	7	8	9	10	10	11	12	13	14	17	20	24	29	39	60	125	213	260	177	94	60	47	40	35	25	20	14	9	0	
3.0	1	2	3	4	5	5	6	6	7	8	8	9	10	12	14	16	19	23	29	48	55	195	247	167	93	60	47	40	29	22	15	10	0	
IA/P = 0.30	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	IA/P = 0.30		
0.0	22	58	146	308	424	422	367	303	234	145	111	92	84	79	74	67	62	57	50	43	36	33	30	26	22	20	17	0	0	0	0			
.10	0	0	4	16	44	112	243	364	402	379	328	266	166	120	97	86	80	75	68	62	57	51	44	37	33	30	27	22	21	17	0	0		
.20	0	0	0	3	12	33	86	190	306	370	376	344	292	189	132	103	89	82	77	69	63	58	51	44	37	33	30	27	23	21	17	0	0	
.30	0	0	0	0	2	8	25	65	149	254	331	361	350	261	175	126	100	88	31	73	66	60	53	46	39	35	31	28	23	21	18	0	0	
.40	0	0	0	0	0	1	6	19	50	116	208	290	338	346	232	195	138	107	91	83	74	67	60	54	47	40	35	32	28	23	21	18	0	0
.50	0	0	0	0	0	0	1	14	38	90	168	250	308	333	256	180	131	104	89	78	71	63	56	49	42	36	33	29	23	21	18	0	0	
.75	0	0	0	0	0	0	0	2	6	17	43	89	150	213	299	286	229	171	129	104	85	75	65	58	51	44	38	34	30	24	22	18	0	0
1.0	0	0	0	0	0	0	0	0	1	3	9	24	53	153	253	288	257	200	150	105	85	72	62	55	48	41	36	32	26	22	19	0	0	
IA/P = 0.50	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	IA/P = 0.50		
0.0	116	193	221	221	200	165	129	110	99	95	92	87	81	77	72	65	56	49	45	41	37	32	30	25	0	0	0	0	0	0	0	0	0	0
.10	0	0	0	0	1	23	85	157	205	214	205	178	138	115	102	96	92	88	82	77	73	66	57	50	46	42	38	32	30	26	0	0		
.30	0	0	0	0	0	1	15	62	125	175	201	203	187	147	121	105	98	94	89	83	78	73	66	58	50	46	42	38	32	30	26	0	0	
.40	0	0	0	0	0	0	0	7	32	76	125	164	189	179	148	123	107	99	94	87	81	76	69	62	53	48	44	39	33	30	26	0	0	
.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IA/P = 0.75	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	IA/P = 0.75		
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IA/P = 1.0	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	IA/P = 1.0		
RAINFALL TYPE = III	+	+	+	+	+	+	+	+	+	+	+	+	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	RAINFALL TYPE = III		

(210-VI-TR-55, Second Ed., June 1986)

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—*continued*

(210-VI-TR-55, Second Ed., June 1986)

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—continued

TRVL TIME (hr)	11.3	11.6	11.9	12.1	12.3	12.5	12.7	13.0	13.2	12.8	13.4	13.8	14.3	15.0	15.5	16.0	16.5	17.0	17.5	18.0	19.0	20.0	21.0	22.0	23.0								
IA/P = 0.10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+								
TC = 0.5 HR *	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*							
IA/P = 0.10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+								
0.0	21	35	54	70	97	144	217	316	397	411	388	330	214	139	99	78	67	60	52	47	36	31	26	23	21	18							
.10	19	24	30	43	50	64	86	125	186	273	355	392	296	194	129	94	75	65	56	49	38	33	28	24	21	19							
.20	18	23	29	40	47	58	77	109	161	235	315	367	382	318	218	145	115	103	80	68	57	50	44	39	33	28							
.30	16	21	26	34	38	44	53	69	95	139	203	278	337	367	289	199	135	98	77	62	54	46	35	30	25	22							
.40	16	20	25	33	36	41	49	62	84	121	176	244	306	358	306	220	151	107	83	64	55	47	41	35	30	25							
.50	14	18	22	28	31	35	39	46	57	75	106	152	213	323	346	282	202	140	102	73	59	53	42	37	32	27	23						
.75	12	16	20	25	28	30	34	38	45	56	75	104	145	246	319	308	252	187	135	89	67	53	44	39	33	28	24						
1.0	10	12	16	20	22	23	25	28	31	34	39	47	60	110	197	280	309	279	220	138	90	63	49	42	37	31	26	23					
1.5	6	8	10	13	14	15	17	18	19	21	23	25	27	34	49	82	143	218	283	271	203	116	68	51	43	37	32	27	21	16			
2.0	3	5	7	9	10	11	12	13	14	15	16	17	19	22	27	34	50	82	135	226	265	211	114	67	50	42	37	31	23	18			
2.5	2	3	4	6	7	8	9	10	11	12	13	16	18	22	26	34	50	102	182	249	197	111	67	50	42	36	31	23	18	13			
3.0	1	1	2	3	4	4	6	7	8	9	10	12	14	16	19	23	34	63	144	238	201	121	72	43	31	23	15	9	10				
4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
IA/P = 0.10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+						
0.0	0	0	1	4	15	40	101	198	295	345	325	232	161	122	100	88	80	72	65	59	53	46	39	34	31	28	23	21	18				
.10	0	0	0	1	3	11	30	77	158	249	313	335	329	253	178	132	106	91	82	73	60	53	47	40	35	31	28	23	21	18			
.20	0	0	0	0	2	8	23	59	125	208	278	315	324	271	196	144	112	95	85	75	61	54	47	40	35	32	28	23	21	18			
.30	0	0	0	0	0	0	0	2	6	17	45	98	171	242	291	313	249	182	136	108	92	80	71	63	56	49	42	36	33	29			
.40	0	0	0	0	0	0	0	1	3	10	34	77	140	208	264	304	263	198	148	115	97	81	72	64	57	50	43	37	33	30			
.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
IA/P = 0.10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
0.0	0	0	0	0	0	0	0	3	24	68	124	174	190	190	162	133	114	103	97	92	85	80	75	68	60	52	47	43	39	33	30	26	
.10	0	0	0	0	0	0	0	2	17	51	100	149	177	186	169	140	119	106	99	93	86	81	75	69	61	52	47	43	39	33	30	26	
.20	0	0	0	0	0	0	0	1	12	38	79	126	160	181	173	147	124	109	101	95	88	81	76	69	62	53	48	44	39	33	30	26	
.30	0	0	0	0	0	0	0	1	8	28	62	105	141	176	165	141	120	107	99	91	84	78	71	64	56	49	45	41	33	31	26	0	
.40	0	0	0	0	0	0	0	0	1	6	20	48	86	123	172	172	146	125	111	101	92	85	79	72	65	56	50	45	41	34	31	26	0
.50	0	0	0	0	0	0	0	0	0	15	37	70	105	157	167	151	130	114	104	94	87	79	73	66	57	50	45	41	34	31	26	0	
.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
RAINFALL TYPE = 111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
* * * TC = 0.5 HR *	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		

SHEET 5 OF 10

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—continued

TRVL (hr)	TIME (hr)	HYDROGRAPH TIME (HOURS)												IA/P = 0.10	IA/P = 0.10																			
		11.3	11.6	11.0	11.0	12.1	12.3	12.5	12.4	12.6	12.7	13.0	13.3																					
0.0	15	19	24	32	37	44	54	71	98	136	181	227	264	297	270	215	164	128	103	78	64	52	43	36	31	26	23	21	16	14	12	0		
.10	13	17	22	28	31	35	41	49	64	87	120	161	205	273	289	254	201	155	122	90	71	56	45	38	33	28	24	21	17	14	12	0		
.20	13	16	21	27	29	33	39	46	53	77	105	142	184	257	285	263	214	167	130	95	74	57	46	39	33	28	24	21	17	14	12	0		
.30	12	16	20	26	28	31	36	42	53	69	93	126	165	240	279	268	225	178	139	100	77	59	47	39	34	29	25	22	17	15	12	1		
.40	11	14	13	23	25	27	30	34	40	48	62	83	112	185	251	276	256	213	163	118	87	65	50	41	35	30	26	23	18	15	12	1		
.50	11	13	17	22	24	26	29	32	37	45	56	74	99	167	235	256	230	223	179	126	92	67	51	42	36	31	26	23	18	15	12	1		
.75	8	10	13	17	19	19	21	23	25	31	36	44	72	122	186	239	258	234	189	136	90	62	48	40	34	29	25	20	16	12	2			
1.0	6	9	11	14	15	17	18	20	21	23	25	32	46	75	124	185	234	253	226	170	110	71	53	43	37	31	27	21	16	13	4			
1.5	4	6	8	10	11	12	13	14	15	16	17	19	21	25	32	46	74	119	170	230	239	179	108	70	52	43	36	31	23	18	13	7		
2.0	2	3	4	6	7	7	8	9	10	11	12	13	16	18	22	28	38	58	111	179	228	185	116	75	54	44	37	27	21	14	9			
2.5	1	2	4	4	5	5	6	6	7	8	8	9	11	13	15	18	22	28	46	87	167	219	176	113	73	54	43	31	23	15	10			
3.0	0	0	1	2	2	2	3	3	3	4	4	5	5	7	8	10	12	14	16	21	32	68	156	210	179	120	74	56	37	27	16	11		
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
...	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
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Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution

(210-VI-TR-55, Second Ed., June 1986)

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—continued

(210-VI-TR-55, Second Ed., June 1986)

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution

(210-VI-TR-55, Second Ed., June 1986)

Exhibit 5-III: Tabular hydrograph unit discharges (csm/in) for type III rainfall distribution—continued

(210-VI-TR-55, Second Ed., June 1986)